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Effects of Organic and Inorganic Fertilizers on Soil Properties, Yield and Yield Components of Maize (*Zea mays L.*) Grown on an Andisols at Hawassa Zuria, Ethiopia

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Abstract

The study was carried out to determine the influence of organic and inorganic fertilizers on maize yield and soil fertility; to determine economically optimum organic and inorganic fertilizer combinations for maize production. The study was performed in a randomized complete block design consisting of 10 treatments and 3 replications. The treatments were: Control, 100% of R-NP (138 N and 92 P), 100% of vermicompost, 100% of conventional compost, 25% R-NP +75% of vermicompost, 50% of R-NP + 50% of vermicompost, 75% of R-NP+25% of from vermicompost, 25% of R-NP +75% of conventional compost, 50% of R-NP+50% of conventional-compost, 75% of R-NP +25% of conventional-compost. All rates of vermicompost and conventional compost were applied based on N equivalence. Results indicate that applications of inorganic fertilizers with a combination of organic source fertilizers were increases maize yield and yield components and improves the nutrient status of the soil. The highest maize grain yield (7494.3 kg ha^{-1}) and above-ground biomass yield (18718.0 kg ha^{-1}) was obtained from the applications of 50% recommended NP fertilizer plus 50% vermicompost which is based on the recommended N equivalent respectively. Similarly, we found that a combination of both inorganic and organic fertilizers application also is the best strategy to improve major soil nutrients, maintain soil fertility. The economic analysis revealed that the highest net benefit of (108,872.00 ETB ha^{-1}) was obtained from the application of 50% recommended NP fertilizer plus 50% vermicompost. Yet, the lowest yield and net benefit value were attained from the control or unfertilized plot. Therefore, this study suggests that an appropriate proportion of organic fertilizer with inorganic fertilizer not only for higher yield maize production with an assurance of potential economic returns to the small hold farmers but also improve and maintain the soil fertility and should be adopted with similar soil type and agro-ecologies.

Keywords: Grain yield; Inorganic fertilizers; Maize; Organic; Soil fertility

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Introduction

Ethiopia is the fifth largest producer of Maize (***Zea mays L.***) in Africa and smallholder farmers make up 94% of crop production with area coverage (16%) and production (26%) with about 6.5 million tons of production [1]. Nevertheless, the average estimated yields of maize for smallholder farmers in the country are about 3.2 t ha^{-1} which is much lower than the yield recorded under demonstration plots of 5-6 t ha^{-1} [1]. Maize is an exhaustive cereal crop having higher potential than other cereals and absorbs a large number of nutrients from the soil during different growth stages. However, in Ethiopia, low soil fertility and low levels of input use are some of the major constraints for crop production [2]. Tropical smallholder farming systems including Ethiopia there are many interrelated factors, both natural and manmade, cause soil fertility decline. This decline may occur through leaching, soil erosion, lack of soil fertility restoring input, unbalanced nutrient use, and crop harvesting [3].

Unless the nutrients are replenished using organic or mineral fertilizers, or partially returned through crop residues, or rebuilt more comprehensively through traditional fallow systems that allow restoration of nutrients and reconstruction of soil organic matter, soil nutrient levels decline continuously. Thus, the recently acquired soil inventory data revealed that the deficiencies of most nutrients such as nitrogen (86%), phosphorus (99%), potassium (7%), sulfur (92%), born (65%), zinc (53%), copper, manganese, and iron are wide spread in Ethiopian soils [4]. Therefore, to alleviate nutrient deficiencies in soils and reduction in crop yield using affordable technologies were must. This include specially the use of combinations of organic and inorganic fertilizers and different integrated soil fertility management [5-9].

Achieving high maize yield requires an adequate and balanced supply of nutrients as declining soil fertility is a prominent constraint for maize production [10]. Many scholars who reported higher maize yields through the application of balanced use of high-quality organic inputs in combination with inorganic fertilizer as compared to the sole application of inorganic fertilizers [11-16]. Similarly, this has also confirmed works by Negassa et al. [17] were found that the application of NP and FYM gave higher yields than the application of either NP or FYM alone for maize production. Zelalem et al. [18] found that the application of 4 t FYM ha^{-1} incorporated with 75/60 kg of N and P ha^{-1} was an economical and profitable combination in boosting maize yield. Similarly, Ahmad et al. [19] found highest grain and biological yields due to the combined application of 50% N from FYM and 50% NPK through inorganic fertilizers. Various studies revealed that the application of 50% organic manure along with 50% nitrogen from urea resulted in higher yield and yield components and maximum benefits for smallholder farmers in the tropics.

Obviously, addition of inorganic fertilizers can boost crop yield but it has own problem related to deterioration in soil properties and its cost affordability to smallholder farmers has to be removed. Moreover, sole application of inorganic fertilizer cannot been guarantee for long-term crop productivity in many soils since they are not effective to maintain and improve soil fertility. Therefore, the integration of organic fertilizers like vermicompost and conventional composts with inorganic fertilizer sources were a viable option in improving maize yields without degrading soil fertility status. Moreover, very little information is available on the effects of abandoning manure application on crop productivity and soil quality. Therefore, keeping the above points in view, this study was undertaken to determine the influence of organic and inorganic fertilizers on yield and yield components of maize and soil fertility and to determine the economically optimum rate of organic and inorganic fertilizer rate for maize in Hawassa zuria, Sidama, Ethiopia.

Materials and Methods

Experimental site

This study was conducted at Hawassa Zuria district on farmer field for three consecutive main crop seasons (2017-2019). The experimental site geographically located at (6^o 57' N and 38^0 15' E to 7^0 10') with an altitude of 1850 m asl. The average mean annual rainfall and temperature are about 800mm-1100 mm and the average minimum and maximum monthly temperatures are 12°C and 26.7°C respectively. The rainy seasons are identified by the month that effective rainfall occurs. The rainfall is bimodal with longer growing periods from mid-May to mid- September and about 87% of the total rainfall and peak of the area occurs from mid-July to the end of August and which caused soil erosion and nutrient loss. According to FAO [20] the dominant soil type of the site is Andosols, with the textural class of silty loam. The dominant crop in the area is maize.

Treatments and experimental design

The experiment was established in a randomized complete block design (RCBD) in a factorial arrangement with three replications. It consisted of 10 treatments in a combination of organic (vermicompost/conventional compost) and inorganic fertilizers and the organic fertilizer sources was adjusted based on inorganic N equivalence **(Table 1).**

Organic fertilizer (vermicompost and conventional compost) was prepared at Wondo Genet Agricultural Research Center. Three representative sub-samples were taken to analyses selected chemical properties such as pH, EC, OC, TN, Avail-P, and C: N ratio. The collected samples were air-dried, ground, and sieved through 2 mm sieve whereas a 0.5 mm sieve was used for OC and TN. The selected chemical properties of the organic inputs used in this study are presented in **Table 2.** The improved maize variety (BH-546) was used as test crop and sown in rows with an inter- and intra- row spacing of 75 × 30 cm. Phosphorus-containing fertilizers triple superphosphate (TSP) was basally applied once at sowing to minimize losses and increase nutrient use efficiency. Nitrogen-containing fertilizer used from the Urea source and applied in the row two times; half at sowing and the other half during the maximum growth or tasseling period. Other agronomic management practices were applied as per recommendation.

Crop harvest, soil sampling, and analyses

At maturity, 3 m^2 of maize was manually harvested from the middle of each plot to determine the plant height, ear height, ear length, above-ground biomass, grain yield; the grain yield which was adjusted to 12.5% moisture content. Before the imposition of the treatments, one composite soil sample was taken at a depth of 0-20 cm and after crop harvest representative soil samples were collected immediately from each experimental unite to investigate the treatment effects on soil chemical properties. The soil samples were air-dried, were processed, and analyzed for soil texture, pH, organic matter, total nitrogen, available phosphorous, total sulfur, and cation exchange capacity were analyzed following the standard procedures' outlines.

Economic analysis

The economic returns from the application of each treatment were calculated based on the partial budgeting, which included only added costs and added benefits from the control treatment

[21]. The average yield was adjusted downwards by 10% to reflect the difference between the experimental plot yield. Added costs included all the expenses for buying inorganic fertilizers (15.50 ETB kg^{-1} TSP and 10.25 ETB kg^{-1} Urea), conventional compost (1.50 ETB kg^{-1}), and vermicompost (2.50 ETB kg^{-1}), while the added benefits referred to the gain obtained by selling maize grain was 14.50 ETB kg^{-1} at the local market price.

Statistical analysis

The data were analyzed by using a two-way analysis of variance (ANOVA) using statistical analysis software (SAS) version 9.4 [22]. Whenever the treatment effects were significant, mean separations were made using the least significant difference (LSD) test at ($p \leq 0.05$) level of probability test by proc-mixed analysis [23].

Results and Discussion

Physicochemical properties of initial soil, vermi-compost, and conventional compost

The analysis results indicated that soil particle size distribution of the experimental site was in proportions of sand, silt, and clay (39%, 31%, and 30% respectively **(Table 2).** Based on FAO [20] soil textural classification the textural class of the soil of was clay loam. The pH water (1:2.5) level of experimental site soil result indicates that 6.7 **(Table 2).** According to Hazelton and Murphy [24] interpreting the soil pH of the site was near neutral and this most suitable for plant growth. It is a vital role in determining several chemical reactions and in influencing plant growth by affecting the activity of soil microorganisms and altering the solubility and availability of most of the essential plant nutrients and particularly the micronutrients such as Fe, Zn, B, Cu, and Mn [25].

The analysis result shows that the available P content was 6.4 mg kg^{-1} and was presented in **Table 2.** The available P content of the soil was low according to the rating [26]. Okalebo et al. [27] reported that low soil available P values close to or below 10 mg P kg^{-1}, the level below which P responses are expected. The total nitrogen content of site was 0.12%, which is ranged medium according to Tekalign [28]. Similarly, organic carbon content was 2.75%, which is rated as moderate level according to Tekalign [28] classification. The total S content of the site is 22.51 mg kg^{-1}. According to Havlin et al. [29], the available S content of the soil in the study area was low. Based on Hazelton and Murphy [24] rating, the CEC of the soils are classified <5, 5-15, 15-25, 25-40, and >40 c mol kg^{-1} soil as very low, low, medium, high, and very high. Thus, the CEC was 23-cmolc kg^{-1} and rated as medium.

Vermicompost and Conventional Compost

The chemical compositions of vermicompost and conventional compost are presented in **Table 2** below. The result shows that the pH water (1:2.5) of vermicompost and conventional compost were 7.8 and 7.4, respectively. Based on Hazelton and Murphy [24] interpretation the organic materials were slightly alkaline and it is the most suitable for plant growth. The total nitrogen and organic carbon contents of the vermicompost were 2.73% and 28.1%, respectively while the conventional compost contained 1.93% total nitrogen and 30.1% organic carbon. This indicating that vermicompost has better total nitrogen over that of conventional compost. This was possibly due to the addition of organic N by earthworms through their excretory products, mucus, body fluid, enzymes, and even through decaying tissues of dead worms. Suthar [30] who described that earthworms enhanced the total N level in vermicomposting. Yadav et al. [31] reported total organic carbon reduction values ranging between 26 and 66% during vermicomposting of wastes of various sources. Suthar [32] noted that the total N (range 2.49–3.17%) was higher in the end product and the final N content could be related to the quality of the substrate used for worm feeding and probably because of mineralization of the organic matter. The available P of vermicompost and conventional compost were 1.25 g kg^{-1} and 0.95 g kg^{-1}, respectively. Similar result was obtained by Marlin and Rajesh Kumar [33] who reported that vermicomposting had higher available P (2.68-3.61%). During vermicomposting, the release of available P content from the organic waste occurs partly by the earthworm gut phosphatases, and further release of P might be attributed to the P-solubilizing microorganisms present in the worm casts, causing conversion of phosphorus (P) to forms that are more bio-available to plants [34]. The K content on vermicompost (1.69) and conventional compost (0.92). In earlier studies, K values between 0.54% and 1.72% were reported [35]. The C: N ratio of the content on vermicompost and conventional compost is 28.1% and 30.1%, respectively. According to Kaushik and Garg [36], pointed out the decrease of carbon/nitrogen ratio is due to the rapid decomposition of the organic waste, and the mineralization and stabilization during the process of vermicomposting.

Soil chemical characteristics after crop harvest

To investigate the effects of organic and inorganic fertilization on soil fertility soils samples were taken from each experimental unit after last maize harvest. Accordingly, the result revealed that combined application of organic and inorganic fertilizer had bring significant change on soil fertility and showed a positive effect on the soil pH, organic carbon content, total nitrogen, CEC, available P, Available K and CEC **(Table 3).** The soil pH significantly improved due to the addition of different treatments, the maximum 7.9 was observed from the plot where treated with 50% vermicompost based on N equivalency plus 50% recommended NP fertilizer ha^{-1}. However, the minimum was observed at the control plot (non-fertilized). This indicates an improvement in the soil fertility status due to integrated nutrient management [16]. Similarly, the highest soil organic carbon content 3.5% and 2.9% were obtained from the combined application of 50% vermicompost and conventional compost based on N equivalency with 50% recommended NP fertilizer ha^{-1}, respectively **(Table 4).** However, the lowest soil organic carbon contents were obtained from control or unfertilized plot and followed by the application of organic fertilizer from conventional and vermicompost and 100% recommended rate of NP alone **(Table 3).**

These results were consistent with the investigation of some authors; increased organic carbon due to the application of

Table 1 Details of treatment combination.

Treatments	Fertilizer types
T1	Control
T2	100% of R-NP (138 N and 92 P)
T3	100% of vermicompost
T4	100% of conventional
T5	25% R-NP +75%
T6	50% of R-NP + 50% of vermicompost
T7	75% of R-NP+25% of vermicompost
T8	25% of R-NP +75% of conventional compost
T9	50% of R-NP+50% of conventional-compost
T10	75% of R-NP +25% of conventional-
Note: R-NP-which is recommended Nitrogen and Phosphorous Where: Organic fertilizers were applied based on N-equivalence	

Table 2 Some physic-chemical properties of the soil, vermicompost, and conventional compost prior to treatment application.

Properties	Soil	Vermicompost	Conventional Compost
Textural	Silt Loam	--	--
Sand	39%	--	--
Silt	31%	--	--
Clay	30%	--	--
pH H_2O (1:2.5)	6.7	7.8	7.4
Organic Carbon (%)	2.75	28.1	30.1
Total Nitrogen (%)	0.12	2.72	1.93
Available P (g kg^{-1})	6.4	1.25	0.95
K (g kg^{-1})	1.2	1.69	0.92
Total S mg kg^{-1}	22.51	--	--
CEC ($Cmol^{+}$ kg^{-1})	23	--	--
C: N	--	10.33	15.59
MC%	--	58.1	68.5

Table 3 Treatments effects on some s physicochemical properties of soil after crop harvest.

No	Treatments	pH	OC%	TN%	P (g kg^{-1})	CEC (Cmol kg^{-1}
1	Control	6.8	1.3	0.05	6.5	22.1
2	100% of R-NP (138 N and 92 P)	7.1	2.0	0.12	8.2	27.1
3	100% of vermicompost	7.7	1.9	0.13	10.5	25.9
4	100% of conventional	7.5	1.7	0.11	9.4	24.5
5	25% R-NP +75% of vermicompost	7.3	2.3	0.17	10.5	29.3
6	50% of R-NP + 50% of vermicompost	7.9	3.5	0.41	19.5	36.1
7	75% of R-NP+25% of vermicompost	7.6	2.5	0.15	12.7	28.1
8	25% of R-NP +75% of conventional compost	7.7	2.1	0.15	10.3	26.9
9	50% of R-NP+50% of conventional compost	7.7	2.9	0.27	16.6	35.3
10	75% of R-NP +25% of conventional compost	7.4	2.2	0.14	11.9	27.6

organic manures, subsequently improved crop performance and soil characteristics. Further, these results are also in concurrence with Shisanya et al. [37] who found that corn yield was increased by 35% when combined (inorganic and organic) nutrients were applied. Combined application of organic and inorganic nutrient sources improved synergism and synchronization between nutrient release and plant recovery thus resulted in better crop growth and yield. Soil nutrients status of after application organic and inorganic fertilizer total nitrogen and available phosphorus and CEC were increased **(Table 3).** The result was revealed that the maximum TN (0.41%) available phosphorus (19.5 g kg^{-1}) and CEC (36.1 $Cmol_c$ kg^{-1}) were obtained from the combined application of 50% vermicompost based on N equivalency plus 50% recommended NP fertilizer ha^{-1}. This finding was in lined with Mubeen et al. [38] who found that combined application of organic and inorganic fertilizers is considered a good option to enhance nutrient recovery, increase the nutrient status of soil, plant growth, and ultimate yield.

Similarly, Huang et al. [39] also reported that combined application of organic and inorganic nutrient sources improved synergism and synchronization between nutrient release and plant recovery thus resulted in better crop growth and yield. Finally, from this study, we found that the best strategy to improve productivity

Table 4 Effects of integrated use of organic and inorganic fertilizers on yield components of maize in 2018-2020 cropping seasons.

Treatment (kg ha^{-1})	2018			2019			2020			Pulled		
	PH	EH	CL	PH	EH	CL	PH	EH	CL	PH	EH	CL
Control	127.9^{d}	89.8^{e}	9.9^{e}	187.9^{c}	91.3^{c}	12.1^{d}	157.3^{d}	118.2^{e}	10.5^{d}	157.7^{f}	100.8^{d}	10.8
100% RNP	224.9^{a}	153.9^{a}	14.2^{a}	218.3^{abc}	112.7^{abc}	15.1^{ab}	266.2^{a}	162.4^{a}	13.1	236.5^{a}	143.0^{a}	14.2^{bc}
100% V.C	148.5^{cd}	107.4^{d}	11.5^{cde}	205.2^{bc}	99.7^{bc}	13.1^{cd}	214.5^{c}	135.9^{d}	11.4^{cd}	189.4^{de}	114.3^{cd}	12.0
100% C.C	160.1^{bcd}	107.0^{e}	12.0^{bcd}	193.4^{bc}	98.7^{bc}	15.5^{ab}	216.7^{c}	145.5^{d}	11.9^{cd}	190.1^{ced}	117.0^{cd}	13.1^{cde}
25% RNP+75% V.C	129.4^{d}	93.0^{de}	10.4^{de}	206.1^{bc}	108.1^{abc}	15.0^{ab}	216.7^{c}	141.7^{bcd}	12.0^{bcd}	184.0^{e}	113.2^{cd}	12.5^{ef}
50% RNP+50% V.C	188.5^{abc}	139.6^{abc}	15.0^{a}	255.1^{a}	132.1^{ab}	15.9^{a}	265.9^{c}	148.1^{abc}	14.9^{a}	236.5^{a}	139.9^{a}	15.2^{a}
75% RNP+25% V.C	202.7^{ab}	137.5^{bc}	14.0^{a}	196.1^{bc}	105.8^{bc}	14.9^{ab}	232.7^{a}	156.0^{abc}	12.9^{abc}	210.5^{bcd}	133.1^{ab}	14.0^{cd}
25% RNP+75% C.C	137.1^{d}	126.6^{c}	13.4^{abc}	203.7^{bc}	110.7^{abc}	14.0^{bc}	216.5^{c}	135.1^{d}	11.7^{cd}	185.8^{e}	124.1^{bc}	13.0^{def}
50% RNP+50% C.C	196.5^{ab}	135.2^{bc}	15.1^{a}	233.1^{ab}	142.3^{a}	16.0^{a}	263.2^{ab}	143.7^{cd}	14.0^{ab}	230.9^{ab}	140.4^{a}	15.0^{ab}
75% RNP+25% C.C	200.3^{ab}	151.2^{ab}	13.5^{ab}	200.3^{bc}	100.1^{bc}	14.4^{abc}	236.1^{bc}	159.7^{ab}	13.4^{abc}	212.2^{bc}	137.0^{ab}	13.8^{cd}
CV	15.9	7.9	10.0	12.1	18.6	7.1	7.4	5.6	9.7	11.8	11.2	8.3
LSD@≤0.05	47.0**	16.0**	2.1**	43.7**	35.2**	1.9*	29.0*	13.8**	2.1**	22.6**	13.4**	1.0*

Where: PH: Plant Height, EH: Ear Height and, CL: Cob Length. RNP: Recommended Nitrogen and Phosphorous, V.C.: Vermicompost and C.C.: Conventional Compost; Numbers followed by the same letter in the same column are not significantly different at 5% probability level

Table 5 Effects of integrated use of organic and inorganic fertilizers on yield of maize in 2018-2020 cropping seasons.

Treatment (kg ha^{-1})	2018			2019			2020			Pulled		
	AgBM	SY	GY	AgBM	SY	GY	AgBM	SY	GY	AgBM	SY	GY
Control	9020^{d}	6595^{e}	2425.1^{ab}	9704^{d}	5545^{c}	4159.1^{d}	14775.0^{c}	10880.0	3895.2^{d}	11166.0^{e}	7673.0^{d}	3493.1^{e}
100% RNP	18889^{a}	12466^{a}	6422.4^{a}	14222^{bc}	8165^{abc}	6057.5^{abc}	18568.0^{abc}	12921.0	5646.2^{bc}	17226.0^{ab}	11184.0^{ab}	6042.0^{bc}
100% RN V.C	11899^{bcd}	7666^{bcd}	4233.1^{bcd}	13926^{cd}	9202^{abc}	4724.4^{cd}	15261.0^{bc}	10470.0	4791.3^{cd}	13695.0^{d}	9112.0^{abcd}	4582.9^{e}
100% RN C.C	11485^{bcd}	7365^{cd}	4119.7^{cd}	13333^{cd}	8818^{abc}	4515.6^{cd}	15378.0^{bc}	10379.0	4999.6^{cd}	13399.0^{de}	8854.0^{bcd}	4544.9^{e}
25% RNP +75%V.C	11051^{cd}	7405de	3645.2^{de}	12148^{cd}	6602^{bc}	5545.9^{bcd}	16072.0^{abc}	11745.0	4326.9^{d}	13090.0^{de}	8584.0^{ad}	4506.0^{e}
50% RNP+50% V.C	17960^{a}	11258^{a}	6701.6^{a}	18889^{a}	11217^{a}	7671.5^{a}	19306.0^{a}	11196.0	8109.8^{a}	18718.^{0}a	11224.0^{a}	7494.^{3}a
75% RNP+25% V.C	18455^{a}	12710^{ab}	5744.4^{ab}	14815^{abc}	9904^{ab}	4911.2^{bcd}	16712.0^{abc}	11046.0	5665.7^{bc}	16660.0^{abc}	11220.0^{a}	5440.5^{cd}
25% RNP+75% C.C	13131^{bc}	8871^{bcd}	4260.1^{bcd}	15704^{abc}	10401^{ab}	5303.1^{bcd}	15766.0^{abc}	10936.0	4830.2^{cd}	14867.0^{cd}	10069.0^{abc}	4797.8^{de}
50% RNP+50% C.C	14535^{b}	8400^{a}	6135.4^{a}	18444^{ab}	11795^{a}	6649.7^{ab}	19080.0^{ab}	12643.0	6436.7^{b}	17353.0^{ab}	10946.0^{ab}	6407.3^{b}
75% RNP+25% C.C	18485^{a}	12971^{bcd}	5513.7^{abc}	12148^{cd}	7484^{abc}	4663.9^{cd}	18162.0^{abc}	13194.0	4968.6^{cd}	16265.0^{bc}	11216.0^{a}	5048.7^{de}
CV	13.7	22.1	18.0	17.8	19.1	20.0	13.5	20.0	12.2	15.8	24.2	17.0
LSD@<0.05	3418.7	3750.0	1520.5	4382.2	4336.4	1882.9	3902.2	4073.5	1118.8	2261.2	2336.8	841.2

Where: AgBM: Above-Ground Biomass, SY: Straw Yield and GY: Grain Yield;
Numbers followed by the same letter in the same column are not significantly different at 5% probability level

and maintain soil fertility, combination use of both inorganic and organic fertilizers was important.

Effects of integrated use of organic and inorganic fertilizers on plant height, ear height, and cob length maize

The variation in plant height, ear height, and cob length of the maize crop for the different treatments is shown in **Table 4.** The pulled mean analysis revealed that of plant height, ear height, and cob length of maize were significantly (<0.01) affected by the application of integrated use of organic and inorganic fertilizers **(Table 4).** The longest plant height (236.5 cm), ear height (139.9 cm), and cob length (15.2 cm) were obtained from the application of 50% of recommended NP plus 50% of vermicompost. However, the shortest plant height, ear height, and cob length were obtained from the control or unfertilized plot. This is because of, more photosynthetic activities of the plant on the account of an adequate supply of nitrogen since it is an essential requirement for ear growth [39].

Effects of integrated use of organic and inorganic fertilizers on above ground biomass, grain yield, and straw yield maize

The pulled mean analysis revealed that the application of organic and inorganic fertilizers had significant effects on above-ground biomass, grain yield, and straw yield of the maize plant **(Table 5).** The maximum above-ground biomass yield (18178.0 kg ha^{-1}), grain yield (7494.3 kg ha^{-1}), and straw yield (11224.0 kg ha^{-1}) of maize were obtained from the combined application of 50% of recommended NP with 50% of N from vermicompost. Conversely, the minimum values were obtained from unfertilized or control plot. The combined addition of 50% of recommended NP with 50% of N from vermicompost was produced higher grain yield, which is superior by 24% and 21% compared to the control and 100% of recommended NP fertilizers, respectively. On the other hand, sole vermicompost application across all years produced statistically similar grain yield. The yield advantage relative to the control (unfertilized) treatment was 115% **(Table 5)** indicating the depletion of the soil and its strong response to fertilizer

Table 6 Effects of integrated use of organic and inorganic fertilizers on economic profitability of maize production.

Treatment (kg ha^{-1})	AGY (kg ha^{-1})	GBV (ETB kg^{-1})	TVC (ETB kg^{-1})	NBV (ETB kg^{-1})	MRR%
Control	3493.1	52396.5	675	51721.5	
100% RNP	6042	90630	3401.5	87228.5	591.8
100% V.C	4582.9	68743.5	3675	65068.5	
100% C.C	4544.9	68173.5	4175	63998.5	
25% RNP+75% V.C	4506	67590	3609	63981	15295.4
50% RNP+50% V.C	7494.3	112415	3543	108872	
75% RNP+25% V.C	5440.5	81607.5	3467.5	78140	
25% RNP+75% C.C	4797.8	71967	6084	65883	1088.0
50% RNP+50% C.C	6407.3	96109.5	5193	90916.5	
75% RNP+25% C.C	5048.7	75730.5	4292.5	71438	

Where, ETB: Ethiopian Birr (Currency); AGY: Adjusted Grain Yield, GBV: Growth Benefit Value, TCV: Total Variable Cost; NBV: Net Benefit Value; MRR: Marginal Rate of Return

application. This is due to the optimum application of organic and inorganic fertilizer were roles in energy provision for seed formation and grain filling. This is an indication that the integrated use of organic and inorganic nutrient sources of fertilizers was advantageous over the use of inorganic fertilizer alone and result in synergy and improved synchronization of nutrient release and uptake by the crop.

This observation is consistent with findings of other researchers who reported higher maize yields through an application of high-quality organic inputs in combination with inorganic fertilizer as compared to sole application of inorganic fertilizers [11,14,15]. Similarly, this has also been confirmed works by Ahmad et al. [19] and Ali et al. [40], Baloch et al. [13], Dilshad et al. [3] and Khan et al. [16] and Sanjiv Kumar [12] that were found that application 50% N through FYM, Compost vermicompost and 50% NPK through inorganic fertilizers or combined use of organic and inorganic sources resulted in highest grain and yield components of maize compared to either organic or mineral fertilizers alone. Similarly, Shilpashree et al. [41] indicated that significantly higher straw and grain yields recorded with the application of 100% (50% N through inorganic fertilizers + 50% N through FYM (vermicompost), 150% (75% N through inorganic fertilizers + 75% N through FYM/vermicompost). And, similar, the results obtained agree with those of Fanuel L et al. and Magda AE et al. [39,42] they found that the production of grain yield might be due to better growth, development, and dry matter accumulation with a proper supply of nutrients to plant and increase in the availability of other plant nutrients with the respective source of nitrogen application.

Economic analysis

The result of the economic analysis revealed that all treatments were economically feasible as the net benefit values were greater than zero (NBV>0) **(Table 6).** On this note, the application of 50% recommended NP fertilizer along with 50% vermicompost was gave highest NPV of (108, 872.00 ETB ha^{-1}) and is the most economically viable treatment. While the control or unfertilized treatment gives the lowest net benefit (51721.50 ETB ha^{-1}). This result is agreed with, Girma and Gebreyes [43] who found that higher net benefit on tef was gained due to the application of 50% vermicompost with 50% N and P fertilizers, whereas the control treatment (no application of input), gave the lowest net benefit in tef. Likewise, the highest marginal rate of the return (MRR%) was attained from the application of 50% recommended NP plus 50% vermicompost **(Table 6).** Similarly, Tolera et al. [44] was reported the highest marginal rate of return of 980% from the application of 50:50% farmyard manure: with recommended NP for barley production.

Conclusion and Recommendations

This investigation indicates that judicious use of integrated organic and inorganic fertilizer is beneficial to maize production and maintaining the soil nutrient balance. Based on the results of this study combination of inorganic and organic fertilizers with an application of 50% recommended NP fertilizer plus 50% vermicompost is recommended to increase the yield of maize and improve soil fertility. The higher grain yield of maize was obtained from the integration of 50% recommended NP fertilizer plus 50% vermicompost. Similarly, the maximum net profit advantage of 108,872.0 ETB ha^{-1} was obtained from the combined application of 50% recommended NP fertilizer with 50% vermicompost and thus recommended for optimum grain yield and economical profitable of maize production in the area. Finally, this study suggests that judicious use of organic fertilizer along with inorganic fertilizer not only for higher maize yield production with an assurance of economic returns but also provides enough nutrients and should be adopted with similar soil type and agro-ecologies.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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